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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 704
Contribution from the Bureau of Public Roads
LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER August 30, 1918

TYPICAL SPECIFICATIONS FOR NON-BITUMINOUS ROAD MATERIALS

By

PRÉVOST HUBBARD, Chemical Engineer, and
FRANK H. JACKSON, JR., Assistant Testing Engineer

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INTRODUCTION.

This publication should be considered as a companion bulletin to "Typical Specifications for Bituminous Road Materials."[1] In it are given a number of typical specifications for the more common nonbituminous materials used in the construction and maintenance of various types of highways. These are grouped mainly according to type of road. In so far as practicable materials of the same class have also been kept together. When a single type of road requires more than one class of nonbituminous material peculiarly suited to that class, all of the materials are treated in the same specification under appropriate subheadings. Thus in specification RC–2, where the requirements for coarse aggregate for concrete base are the same for broken stone or gravel, these materials have been specified together. Also in specifications such as RBC–2, for bituminous concrete, all of the nonbituminous constituents, including broken stone, sand, and filler, are included.

During the summer of 1917 a survey was made of stone quarries in certain sections of the country[2] with the primary object of obtaining data relating to the commercial sizes of broken stone, which would enable the Bureau of Public Roads to recommend a minimum

[1] U. S. Department of Agriculture Bulletin 691.
[2] "Public Roads," vol. 1, No. 2, June, 1918.

number of standard sizes necessary for the various types of roads in which broken stone is used. It was found that, within a very restricted area, revolving screens, with as many as 28 different size openings, were being used to produce broken stone for a comparatively few types of roads. As a rule, the exact size of product for any one type of road is selected by the individual engineer without reference to other products which the crushing plant may be called upon to supply, also without reference to what size or sizes the engineer himself will select for other types of roads. Moreover, great lack of uniformity in the method of specifying sizes of broken stone was found to exist so that the entire subject of broken stone specifications is at present in an almost chaotic condition.

Following the very logical recommendations of the First Conference of State Highway Testing Engineers and Chemists,[1] the specifications for sizes of broken stone, as given in this bulletin, are based upon laboratory screen tests, rather than upon the size of openings in the commercial screen which produces the material. Based upon data secured in the survey previously mentioned, a limited number of sizes has been selected. It is believed that for the commercial production of each size sufficient tolerance has been allowed in the specifications to make practicable the use of revolving screens with the same openings as the maximum and minimum laboratory screens specified for that size. In most cases, the amount passing an intermediate laboratory screen has also been specified with limits (from 25 to 75 per cent) sufficiently wide to include all acceptable commercial products between the maximum and minimum size but reject most products which would be unacceptable.

The different size broken stone products which may be used satisfactorily in constructing various types of road are given in Table I. It will be seen that not more than five different size openings in revolving screens are required for any one type. In order to meet reasonable working conditions, a general tolerance of not less than 5 per cent retained on the maximum screen, and 15 per cent passing the minimum screen, has been allowed. In the case of screenings, when only the maximum size revolving screen would be required ordinarily, as the product would include dust and all other smaller material, from 40 to 80 per cent of material passing the ¼-inch screen is specified. The only other exception is the broken stone for Topeka type bituminous concrete, where at least 20 per cent of material is required to be retained on the ¼-inch screen.

It is realized that just as satisfactory roads may be constructed with sizes of broken stone varying considerably from these specifications. It is believed, however, that the sizes here covered represent average practice and they are recommended for general use as

a means toward standardizing not only specifications for broken stone but also plant practice in the production of broken stone for highway work.

The forms of specification adopted for broken stone as well as other nonbituminous road materials are, in general, those recommended by the First Conference of State Highway Testing Engineers and Chemists.[1] Following each specification is a brief descriptive paragraph, stating the general conditions governing its uses and what modifications may in certain instances be made. More detailed information and advice relative to methods of construction may be obtained upon application to the Bureau of Public Roads.

It is realized that all classes and types of nonbituminous road materials have not been covered, and it is intended to add to the number of these specifications from time to time. For the convenience of engineers, and in order to make this bulletin complete in itself, the methods of test to which reference is made in the specifications, and directions for sampling, are given in an appendix.

TABLE I.—*Relation of commercial revolving screens to laboratory screen requirements for broken stone.*

Type of road.	Revolving screens.				
	3-inch.	2-inch.	1-inch.	½-inch.	¼-inch.
	Per cent passing laboratory screen of same size.				
Water-bound:					
Bottom course	95+	15−			
Top course		95+	15−		
Screenings			95+		40–80
or					
Base or both courses	95+		15−		
Screenings			95+		40–80
Cover for bituminous surface treatment:					
Coarse chips			95+		15−
or					
Fine chips				85+	15−
Bituminous macadam:					
Bottom course	95+	15−			
Top course		95+	15−		
Chips			95+		15−
Screenings			95+		40–80
Bituminous macadam:					
Wearing course		95+	15−		
Chips			95+		15−
Bituminous concrete:					
One-size stone			95+		15−
Chips				95+	15−
Graded bituminous concrete:					
Coarse aggregate			95+		15−
Chips				95+	15−
Bituminous concrete (Topeka):					
Broken stone				95+	80−
Sheet asphalt:					
Binder stone			95+		
Cement concrete pavement:					
Coarse aggregate		95+			15−
Cement concrete base:					
Coarse aggregate	95+				15−

[1] U. S. Department of Agriculture Bulletin 555.

SPECIFICATION RW–1.

Broken Stone for Water-bound Macadam.

General. The broken stone shall consist of angular fragments of rock, excluding granite, gneiss, sandstone, quartzite, schist, shale, and slate, of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter.

The stone shall meet the following requirement:

Physical Properties. French coefficient of wear, not less than 7

Screenings. That portion of the product of the crusher, including the dust of fracture, which when tested by means of laboratory screens will meet the following requirements:

	Per cent.
Passing 1-inch screen	100
Total passing ¼-inch screen	40 to 80

Top Course Stone. That portion of the product of the crusher which when tested by means of laboratory screens will meet the following requirements:

	Per cent.
Passing 2-inch screen, not less than	95
Total passing 1½-inch screen	25 to 75
Retained on 1-inch screen, not less than	85

Bottom Course Stone. That portion of the product of the crusher which when tested by means of laboratory screens will meet the following requirements:

	Per cent.
Passing 3-inch screen, not less than	95
Total passing 2½-inch screen	25 to 75
Retained on 2-inch screen, not less than	85

Methods of Testing. Tests of the physical properties of the rock and of the sizes of broken-stone products shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification is intended to cover stone to be used in the construction of a broken-stone road by the usual water-bound macadam methods. In certain instances the use of granite, gneiss, sandstone, or quartzite may be allowed in the bottom course, provided the material otherwise meets the specification. These types would be excluded from the wearing course, owing to lack of binding qualities found in materials of this nature. The French coefficient of wear of 7.0 is to be considered here in the light of a minimum requirement under rather light traffic conditions, unless the road is to be maintained with a bituminous wearing mat or carpet. The exact value to be inserted should be governed by the character of available material and estimated traffic conditions. For an ordinary water-bound road subjected to moderate traffic, a coefficient of from 9 to 15 would be more satisfactory, while for heavy traffic a value as high as 16.0 might be required. A coefficient of wear of not less than 7.0 is satisfactory when the road surface is to be maintained with a bituminous material.

It is estimated that for an average rock a bottom course 5 inches and a wearing course 3 inches in thickness, before consolidation, will utilize practically the entire product of an ordinary portable crushing outfit and provide sufficient screenings to properly bind the surface, with a slight excess of screenings in the case of the softer grades of rock, which may be used if desired in filling the bottom course.

SPECIFICATION RW–2.

Broken Stone for Water-bound Base.

General. The broken stone shall consist of angular fragments of rock, excluding granite, gneiss, sandstone, quartzite, schist, shale, and slate, of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter.

Physical Properties. The stone shall meet the following requirement:

French coefficient of wear, not less than 5

Screenings. That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than	95
Total passing ¼-inch screen	40 to 80

Coarse Stone. That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

Passing 3-inch screen, not less than	95
Total passing 2-inch screen	25 to 75
Retained on 1-inch screen, not less than	85

Methods of Testing. Tests of the physical properties of the rock and of the sizes of broken-stone products shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification provides primarily for stone to be used in the construction of water-bound base upon which some higher type of wearing course will be placed, preferably after the base has been finally compacted by traffic. For the softer grades of rock it may also serve for both foundation and wearing courses, provided the thickness of each is not less than 4 inches. In case the broken-stone base is not to be water bound, granite, gneiss, sandstone, and quartzite may be allowed.

SPECIFICATION RS–1.

Coarse Broken Stone for Bituminous Surface Treatment.

General. The broken stone shall consist of angular fragments of clean, hard, tough, durable rock of uniform quality throughout, free from soft or disintegrated stone, dirt, or other objectionable matter.

Size. It shall be that product of the crusher, which when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than	95
Retained on ¼-inch screen, not less than	85

Method of Testing. Tests of the size of broken stone shall be made in accordance with the following method:

Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification provides for a broken-stone product which may be used as cover for a bituminous material applied hot to a road surface. For this purpose it should be evenly spread at the rate of 1 cubic yard to every 50 to 75 square yards of treated road surface, depending upon the amount of bituminous material which has been applied per square yard. Under traffic, preferably preceded by rolling, it is expected to produce, in combination with the bituminous material, a wearing mat or carpet. When the treatment of bituminous material is less than ⅓ gallon per square yard a product meeting Specification RS–2 is to be preferred.

SPECIFICATION RS—2.

Fine Broken Stone or Gravel for Bituminous Surface Treatment.

General. The broken stone or gravel shall consist of clean hard tough durable stone, free from soft or disintegrated particles, dirt, or other objectionable matter.

Size. When tested by means of laboratory screens it shall meet the following requirements:

	Per cent.
Passing ½-inch screen, not less than	85
Retained on ¼-inch screen, not less than	85

Method of Testing. Tests of the size of broken stone or gravel shall be made in accordance with the following method:

Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification provides for a product to be used as cover for a bituminous material applied to a road surface. For this purpose 1 cubic yard should cover from 50 to 150 square yards of treated road surface, depending upon the amount of bituminous material which has been applied per square yard. Under traffic it is expected to produce, in combination with the bituminous material, a thin wearing mat or carpet. It may be considered as an alternate for Specification RS–1 and preferable to the latter when the treatment of bituminous material is less than ⅓ gallon per square yard.

SPECIFICATION RB–1.

Broken Stone for Bituminous Macadam.

General. The broken stone shall consist of angular fragments of rock, excluding granite, gneiss, sandstone, quartzite, schist, shale, and slate, of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

Physical Properties. The stone shall meet the following requirements:

French coefficient of wear, not less than	7

Screenings. That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than	95
Total passing ¼-inch screen	40 to 80

Chips. That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than	95
Retained on ¼-inch screen, not less than	85

Top Course Stone. That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 2-inch screen, not less than	95
Total passing 1½-inch screen	25 to 75
Retained on 1-inch screen, not less than	85

Bottom Course Stone.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 3-inch screen, not less than	95
Total passing 2½-inch screen	25 to 75
Retained on 2-inch screen, not less than	85

Methods of Testing.

Tests of the physical properties of the rock and of the sizes of broken-stone products shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification is intended to cover stone to be used in the construction of a water-bound broken-stone base, and a bituminous broken-stone wearing course constructed by the penetration method. If the base is not to be water bound, the use of granite, gneiss, sandstone, or quartzite may be allowed, provided the material otherwise meets the specifications. Practically the entire output of an ordinary portable crushing outfit will be utilized if a bottom course filled with screenings is constructed 5 inches thick and a top course from 2½ to 3 inches thick. The chips should be used to fill the surface voids in the top course after the first application of bituminous material has been made and also as a cover for the second application or seal coat. Such roads may be maintained with surface treatments of bituminous material, covered with material conforming to Specification RS–1 or RS–2.

SPECIFICATION RB—2.

Broken Stone for Bituminous Macadam Wearing Course.

General.

The broken stone shall consist of angular fragments of rock, excluding schist, shale, and slate, of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

Physical Properties.

The stone shall meet the following requirement:

French coefficient of wear, not less than	7

Chips.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than	95
Retained on ¼-inch screen, not less than	85

Coarse Stone.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 2-inch screen, not less than	95
Total passing 1½-inch screen	25 to 75
Retained on 1-inch screen, not less than	85

Methods of Testing.

Tests of the physical properties of the rock and of the sizes of broken stone products shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification covers stone to be used in the construction of a bituminous broken-stone wearing course in which the bituminous material is applied by the penetration method. The maximum size

of 2 inches specified for the wearing course is on the basis of a course 2½ to 3 inches in thickness after consolidation. The chips should be used to fill the surface voids after the first application of bituminous material has been made and also as a cover for the second application or seal coat. Roads of this type may be maintained with surface treatments of bituminous material, covered with material conforming to Specification RS–1 or RS–2.

SPECIFICATION RBC–1.

Broken Stone for One-size Stone Bituminous Concrete Wearing Course.

General.

The broken stone shall consist of angular fragments of rock, excluding schist, shale, and slate, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

Physical Properties.

The stone shall meet the following requirements:

French coefficient of wear, not less than	8
Toughness, not less than	8

Chips.

That portion of the product of the crusher, which, when tested by means of laboratory screens will meet the following requirements:

	Per cent.
Passing ½-inch screen, not less than	95
Retained on ¼-inch screen, not less than	85

Aggregate.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than	95
Total passing ¾-inch screen	25 to 75
Retained on ¼-inch screen, not less than	85

Methods of Testing.

Tests of the physical properties of the rock and of the sizes of broken-stone products shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Toughness, U. S. Department of Agriculture Bulletin 347, p. 15.
3. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification is intended to cover stone to be used in the construction of a bituminous concrete wearing course and seal coat. The broken stone aggregate for the concrete proper is a single size of crusher product with no exact grading limitations. It may therefore produce what is commonly known as an open mix, and will carry from 5 to 7 per cent bitumen. Such mixture may be placed on a well-compacted broken stone or gravel foundation or a cement-concrete foundation so as to produce after rolling a wearing course 2 inches in depth. A seal coat of bituminous material should then be applied and covered with chips in sufficient quantity to take up all excess of bitumen. Such roads may be maintained with surface treatments of bituminous materials, covered with material conforming to Specification RS–2.

SPECIFICATION RBC–2.

Broken Stone, Sand, and Filler for Coarse Aggregate Bituminous Concrete Wearing Course.

BROKEN STONE.

General. The broken stone shall consist of angular fragments of rock, excluding schist, shale, and slate, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

Physical Properties. The stone shall meet the following requirements:

French coefficient of wear, not less than	8
Toughness, not less than	8

Chips. That portion of the product of the crusher, which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing ½-inch screen, not less than	95
Retained on ¼-inch screen, not less than	85

Coarse Aggregate. That portion of the product of the crusher, which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than	95
Total passing ¾-inch screen	25 to 75
Retained on ¼-inch screen, not less than	85

SAND.

General. The sand for fine aggregate shall be composed of sound, durable stone particles, free from a coating of clay or loam.

Grading. When tested by means of laboratory screens the sand shall meet the following requirements:

	Per cent.
Passing ¼-inch screen	100
Total passing 40-mesh sieve	30 to 70
Retained on 200-mesh sieve, not less than	90

MINERAL FILLER.

General. The mineral filler shall consist of limestone dust, dolomite dust, Portland cement, or natural cement. It shall be free from foreign or other objectionable material.

Fineness. When tested by means of laboratory sieves, the mineral filler shall meet the following requirements:

	Per cent.
Passing 30-mesh sieve	100
Total passing 200-mesh sieve, not less than	65

Methods of Testing. Tests of the physical properties of the rock and of the size or mechanical analysis of broken stone, sand, and mineral filler shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Toughness, U. S Department of Agriculture Bulletin 347, p. 15.
3. Size of broken stone, U. S. Department of Agriculture Bulletin 555, p. 32.
4. Mechanical analysis of sand and mineral filler, U. S. Department of Agriculture Bulletin 555, p. 33.

This specification is intended to cover the mineral constituents of a roughly proportioned bituminous concrete consisting of from 45 to 60 per cent broken stone coarse aggregate, from 30 to 45 per cent sand (fine aggregate), from 3 to 5 per cent mineral filler, and from 5 to 8 per cent bitumen. Such a concrete is similar in character to that described under Specification RBC–1, but is a closer mix. It should preferably be placed upon a cement concrete foundation

so as to produce, after rolling, a wearing course 2 inches in depth. A seal coat of bituminous material should then be applied and covered with chips in sufficient quantity to take up all excess of bitumen. Such roads may be maintained with surface treatments of bituminous material, covered with material conforming to Specification RS–2.

SPECIFICATION RBC–3.

Broken Stone, Sand, and Filler for Fine Aggregate Bituminous Concrete Wearing Course.

BROKEN STONE.

General. The broken stone shall consist of angular fragments of rock, excluding schist, shale, and slate, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

Size. It shall be that product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing ½-inch screen, not less than	95
Retained on ¼-inch screen, not less than	20

SAND.

General. The sand shall be composed of sound durable-stone particles, free from a coating of clay or loam.

Size. When tested by means of laboratory screens the sand shall meet the following requirements:

	Per cent.
Passing ¼-inch screen	100
Retained on 200-mesh sieve, not less than	90

MINERAL FILLER.

General. The mineral filler shall consist of limestone, dust, dolomite dust, Portland cement, or natural cement. It shall be free from foreign or other objectionable material.

Fineness. When tested by means of laboratory sieves, the mineral filler shall meet the following requirements:

	Per cent.
Passing 30-mesh sieve	100
Total passing 200-mesh sieve, not less than	65

TOTAL MINERAL AGGREGATE.

General. The total mineral aggregate shall consist of a uniform mixture of the broken stone, sand, and mineral filler, the required grading of each being such as to produce, when properly proportioned, a mixture conforming to the following limitations for grading. The exact proportion of each constituent producing a total mineral aggregate within these limitations shall be as directed by the engineer.

Grading. When tested by means of laboratory screens and sieves the total mineral aggregate shall meet the following requirements:

	Per cent.
Passing ½-inch and retained on ¼-inch screen	5 to 10
Passing ¼-inch screen and retained on 10-mesh sieve	11 to 25
Passing 10-mesh and retained on 40-mesh sieve	7 to 25
Passing 40-mesh and retained on 80-mesh sieve	11 to 36
Passing 80-mesh and retained on 200-mesh sieve	10 to 25
Passing 200-mesh sieve	5 to 11

Tests of the size or mechanical analysis of broken stone, sand, and mineral filler shall be made in accordance with the following methods: **Methods of Testing.**

1. Size of broken stone, U. S. Department of Agriculture Bulletin 555, p. 32.
2. Mechanical analysis of sand and mineral filler, U. S. Department of Agriculture Bulletin 555, p. 33.
3. Grading of total mineral aggregate, U. S. Department of Agriculture Bulletin 555, pp. 32 and 33.

This specification is intended to cover the mineral constituents and grading for bituminous concrete of a modified Topeka, or stone-filled, sheet asphalt type. It is so drawn that from 10 to 50 per cent of broken stone will be required and the mixture of very fine broken stone and sand will possess a satisfactory sheet asphalt grading. Such an aggregate will carry from 7 to 11 per cent of bitumen. It should preferably be placed upon a cement concrete foundation to a compacted depth of 2 inches. No seal coat will ordinarily be required, and maintenance should consist only in patching with bituminous concrete until it is necessary to replace the entire wearing course.

SPECIFICATION RBC–4.

Broken Stone, Sand, and Filler for Binder Course and Sheet Asphalt Wearing Course.

BROKEN STONE FOR BINDER COURSE.

The broken stone shall consist of angular fragments of rock, excluding schist, shale, and slate, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone, and when tested all of the broken stone shall pass a 1-inch laboratory screen. **General.**

The stone shall meet the following requirement: **Physical Properties.**

Toughness, not less than	8

SAND FOR BINDER COURSE.

The sand shall be composed of sound durable stone particles, free from a coating of clay and loam, which when tested shall all pass a ¼-inch laboratory screen. **General.**

TOTAL MINERAL AGGREGATE FOR BINDER COURSE.

The total mineral aggregate shall consist of a uniform mixture of the broken stone and sand, the required grading of each being such as to produce, when properly proportioned, a mixture conforming to the following limitations for grading. The exact proportion of each constituent producing a mineral aggregate within these limitations shall be as directed by the engineer. **General.**

When tested by means of laboratory screens and sieves the total mineral aggregate shall meet the following requirements: **Grading.**

	Per cent.
Passing 1-inch and retained on ½-inch screen	15 to 65
Passing ½-inch screen and retained on 10-mesh sieve	20 to 50
Passing 10-mesh sieve	15 to 35

SAND FOR SHEET-ASPHALT WEARING COURSE.

General. The sand shall be composed of sound, durable, angular stone particles, free from a coating of clay or loam.

Grading. When tested by means of laboratory sieves the sand shall meet the following requirements:

	Per cent.
Passing 10-mesh sieve	100
Total passing 10-mesh and retained on 40-mesh sieve	12 to 50
Passing 10-mesh and retained on 20-mesh sieve	2 to 15
Passing 20-mesh and retained on 30-mesh sieve	5 to 15
Passing 30-mesh and retained on 40-mesh sieve	5 to 25
Passing 40-mesh and retained on 50-mesh sieve	5 to 30
Passing 50-mesh and retained on 80-mesh sieve	5 to 40
Total passing 80-mesh and retained on 200-mesh sieve	20 to 40
Passing 80-mesh and retained on 100-mesh sieve	6 to 20
Passing 100-mesh and retained on 200-mesh sieve	10 to 25
Passing 200-mesh sieve	0 to 5

MINERAL FILLER FOR SHEET-ASPHALT WEARING COURSE.

General. The mineral filler shall consist of limestone dust, dolomite dust, Portland cement, or natural cement. It shall be free from foreign or other objectionable material.

Fineness. When tested by means of laboratory sieves, the mineral filler shall meet the following requirements:

	Per cent.
Passing 30-mesh sieve	100
Total passing 200-mesh sieve, not less than	65

Methods of Testing. Tests of the physical properties of the rock and of the size, mechanical analysis, or grading of broken stone, sand, and mineral filler shall be made in accordance with the following methods:

1. Toughness, U. S. Department of Agriculture Bulletin 347, p. 15.
2. Size of broken stone, U. S. Department of Agriculture Bulletin 555, p. 32.
3. Mechanical analysis or grading of sand and mineral filler, U. S. Department of Agriculture Bulletin 555, p. 33.

This specification is intended to cover the mineral constituents and rough grading of the mineral aggregate of a binder course and the sand and mineral filler for a sheet-asphalt wearing course. The gradings are essentially those included in Specifications for Sheet Asphalt Paving adopted by the American Society of Municipal Improvements in 1915. The aggregate for binder course will carry from 4 to 7 per cent bitumen. It should be laid upon a concrete base so as to produce a thickness after compaction of about 1½ inches.

In order to secure the specified sand grading for the wearing course it may be necessary to combine two or more sands in predetermined proportions. The surface mixture should be composed of sand, mineral filler, and asphalt cement. It should carry from 6 to 20 per cent filler and from 9½ to 13½ per cent bitumen. It should be laid upon the binder course so as to produce a compacted wearing course 1½ or 2 inches thick as desired. Maintenance of the wearing course should consist only in patching with sheet asphalt topping until it is necessary to replace the entire course.

SPECIFICATION RC–1.

Broken Stone and Sand for One-course Portland Cement Concrete Pavement.

BROKEN STONE FOR COARSE AGGREGATE.

General. The broken stone shall consist of fragments of clean durable crushed rock, free from soft, thin, elongated or laminated pieces, disintegrated stone, vegetable, or other deleterious matter.

Physical Properties. The stone shall meet the following requirements:

French coefficient of wear not less than	8
Toughness, not less than	8

Grading. When tested by means of laboratory screens the broken stone for coarse aggregate shall meet the following requirements:

	Per cent.
Passing 2-inch screen, not less than	95
Total passing 1-inch screen	40 to 75
Retained on ¼-inch screen, not less than	85

SAND FOR FINE AGGREGATE.

General. The sand shall consist of clean, hard, durable, uncoated stone particles, preferably siliceous, free from lumps of clay, soft or flakey particles, loam, and all organic matter.

Grading. It shall be well graded from coarse to fine, and when tested by means of laboratory screens and sieves shall meet the following requirements:

	Per cent.
Passing ¼-inch screen	100
Total passing 20-mesh sieve	50 to 80
Total passing 50-mesh sieve, not more than	20
Passing 100-mesh sieve, not more than	5

Not more than 3 per cent by weight shall be removed by the elutriation test.

Mortar Strength Test. When the sand is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand, by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 100 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

Methods of Testing. Tests of the physical properties of the rock, the grading or mechanical analysis of broken stone and sand, and of the mortar tensile strength of sand shall be made in accordance with the following methods:

1. Toughness: U. S. Department of Agriculture Bulletin 347, page 15.
2. Grading of Broken Stone: U. S. Department of Agriculture Bulletin 555, page 32.
3. Mechanical Analysis of Sand: U. S. Department of Agriculture Bulletin 555, page 33.
4. Elutriation Test for Sand: U. S. Department of Agriculture Bulletin 555, page 32.
5. Mortar Tensile Strength Test for Sand: A. S. T. M. Standard Test C9–17.

This specification provides for coarse and fine aggregate to be used in the construction of a one-course Portland cement concrete pavement. While a coefficient of hardness of not less than 16 for the stone for coarse aggregate might well be included under physical properties, a requirement for French coefficient of wear has been used instead, owing to the fact that few laboratories are equipped with a Dorry hardness machine.

The 15 per cent of coarse aggregate passing the ¼-inch screen, which is allowed, is permissible only upon the assumption that

construction specifications will be based upon a fixed proportion of cement to combined coarse and fine aggregate and that the relative amounts of broken stone and sand will be varied as directed by the engineer so as to approximate definite proportions of coarse and fine aggregate. Thus the concrete should be composed of 1 part of Portland cement and 4½ parts of fine and coarse aggregate, each measured separtely and accurately by volume. The concrete should approximate a 1:1½:3 mix, but the engineer should vary the relative proportions of fine and coarse aggregate, depending upon their exact grading so as to obtain a concrete of maximum density.

The concrete should be mixed in a batch mixer for not less than 1½ minutes and the water should be reasonably clear, free from oil, acid, alkali, or vegetable substance, and neither brackish nor salt. Sufficient water should be used to produce a concrete which will flatten out and quake when deposited in place, but not enough to cause it to flow or to separate mortar and coarse aggregate.

SPECIFICATION RC–2.

Broken Stone or Gravel, and Sand for Portland Cement Concrete Base.

BROKEN STONE OR GRAVEL FOR COARSE AGGREGATE.

General. The broken stone or gravel for coarse aggregate shall consist of clean, hard, tough, durable stone. It shall be free from soft, thin, elongated, or laminated pieces, disintegrated stone, vegetable, or other deleterious matter.

Grading. When tested by means of laboratory screens the coarse aggregate shall meet the following requirements:

	Per cent.
Passing 3-inch screen, not less than	95
Total passing 1½-inch screen	40 to 75
Retained on ¼-inch screen, not less than	85

SAND FOR FINE AGGREGATE.

General. The sand shall consist of clean, hard, durable, uncoated stone particles, preferably siliceous, free from lumps of clay, soft or flakey particles, loam, and all organic matter.

Grading. It shall be well graded from coarse to fine, and when tested by means of laboratory screens and sieves shall meet the following requirements:

	Per cent.
Passing ¼-inch screen	100
Total passing 20-mesh sieve, not less than	20
Total passing 50 mesh sieve, not more than	50
Passing 100 mesh sieve, not more than	10

Not more than 5 per cent by weight shall be removed by the elutriation test.

Mortar Strength Test. When the sand is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand, by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

Tests of the grading or mechanical analysis of broken stone or gravel, and sand, and of the mortar tensile strength of sand shall be made in accordance with the following methods: **Methods of Testing.**

1. Grading of broken stone or gravel, U. S. Department of Agriculture Bulletin 555, p. 32. (8)
2. Mechanical analysis of sand, U. S. Department of Agriculture Bulletin 555, p. 33.
3. Elutriation test for sand, U. S. Department of Agriculture Bulletin 555, p. 32.
4. Mortar tensile strength test for sand, A. S. T. M., Standard Test C9–17.

This specification provides for coarse and fine aggregate to be used in the construction of a Portland cement concrete base.

The 15 per cent of coarse aggregate passing the ¼-inch screen which is allowed is only permissible upon the assumption that construction specifications will be based upon a fixed proportion of cement to combined coarse and fine aggregate and that the relative amounts of broken stone or gravel and sand will be varied as directed by the engineer so as to approximate definite proportions of coarse and fine aggregate. Thus the concrete should be composed of 1 part of Portland cement and 9 parts of fine and coarse aggregate, each measured separately and accurately by volume. The concrete should approximate a 1:3:6 mix, but the engineer should vary the relative proportions of fine and coarse aggregate depending upon their exact grading, so as to obtain a concrete of maximum density.

The concrete should be mixed in a batch mixer for not less than 1 minute and the water should be reasonably clear, free from oil, acid, alkali, or vegetable substance, and neither brackish nor salt. Sufficient water should be used to produce a concrete which will flatten out and quake when deposited in place, but not enough to cause it to flow or to separate mortar and coarse aggregate.

SPECIFICATION GW–1.

Gravel for Water-bound Gravel Roads.

General. The gravel shall be composed of fragments of hard, durable rock, of high resistance to abrasion, together with sand and clay or other binding material, and shall be free from thin or elongated pieces.

Quality.

	Per cent.
Cementing value of material under ¼-inch mesh shall be not less than	50
1. For base course:	
(*a*) The gravel, when tested by means of laboratory screens, shall meet the following requirements:	
Passing a 3-inch screen, not less than	95
Total retained on ¼-inch screen	50 to 75
(*b*) The material retained on the ¼-inch screen is known as coarse aggregate. The coarse aggregate, when tested by means of a laboratory screen, shall meet the following requirement:	
Total retained on 1½-inch screen	25 to 75
(*c*) The material passing the ¼-inch screen is known as fine aggregate. The fine aggregate, when tested by means of a laboratory sieve, shall meet the following requirement:	
Total passing 200-mesh sieve	15 to 35
2. For wearing course:	
(*a*) The gravel, when tested by means of laboratory screens, shall meet the following requirements:	
Passing a 2-inch screen, not less than	95
Total retained on ¼-inch screen	50 to 75
(*b*) The material retained on the ¼-inch screen is known as coarse aggregate. The coarse aggregate, when tested by means of a laboratory screen, shall meet the following requirement:	
Total retained on 1-inch screen	25 to 75
(*c*) The material passing the ¼-inch screen is known as fine aggregate. The fine aggregate, when tested by means of a laboratory sieve, shall meet the following requirement:	
Total passing 200-mesh sieve	15 to 35

Method of Testing. Tests of the quality and grading of the gravel shall be made in accordance with the folowing methods:

Cementing value, U. S. Department of Agriculture Bulletin 345, p. 19.
Grading, U. S. Department of Agriculture Bulletin 555, p. 32 (9).

This specification covers the quality and grading of a sand-clay-gravel suitable for use in the construction of a water-bound gravel road. It applies to gravels composed mainly of fragments of quartz or other nonbinding rock types. In cases where the gravel is composed essentially of limestone or other materials which will bond under traffic, considerably less material under 200-mesh may be allowed. The sizes specified contemplate a base course of at least 4 inches, and a wearing course of at least 3 inches in thickness after consolidation. The relative proportions of the various intermediate sizes have been drawn so as to exclude only gravels of manifestly poor grading. In cases where the gravel, although otherwise acceptable, is deficient in sand or clay, such materials, if available, and of a suitable character, may be added in sufficient quantities to bring the grading and cementing value of the gravel to within the limits specified. This should be done by spreading the sand or clay uniformly over the loose gravel surface and thoroughly harrowing with a spike-tooth harrow, after which the surface is consolidated.

In maintaining roads of this type, material as nearly the same as that composing the road surface should be used. In patching, care should be taken that the finished surface after consolidation is smooth and continuous.

SPECIFICATION GBC–2.

Gravel, Sand, and Filler for Coarse Aggregate Bituminous Concrete Wearing Course.

GRAVEL.

General. The gravel shall be composed of sound, hard, durable fragments of rock of high resistance to abrasion and shall contain no particles of shale, slate, coal, or other materials which easily disintegrate. It shall be free from vegetable or other deleterious matter, and shall contain no soft, thin, or elongated pieces.

Pea Gravel. The pea gravel, when tested by means of laboratory screens, shall meet the following requirements:

	Per cent.
Passing ½-inch screen, not less than	95
Retained on ¼-inch screen, not less than	85

Coarse Aggregate. The coarse aggregate, when tested by means of laboratory screens, shall meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than	95
Total passing ¾-inch screen	25 to 75
Retained on ¼-inch screen, not less than	85

SAND.

General. The sand for fine aggregate shall be composed of sound, durable stone particles, free from a coating of clay or loam.

Grading. When tested by means of laboratory screens and sieves, the sand shall meet the following requirements:

	Per cent.
Passing ¼-inch screen	100
Total passing 40-mesh sieve	30 to 70
Retained on 200 mesh sieve, not less than	90

MINERAL FILLER.

General. The mineral filler shall consist of limestone dust, dolomite dust, Portland cement, or natural cement. It shall be free from foreign or other objectionable material.

Fineness. When tested by means of laboratory sieves, the mineral filler shall meet the following requirements:

	Per cent.
Passing 30 mesh sieve	100
Total passing 200 mesh sieve, not less than	65

Methods of Testing. Tests of the grading of the gravel, sand, and filler shall be made in accordance with the following methods:

Grading of Gravel, U. S. Department of Agriculture Bulletin 555, p. 32.
Grading of Sand and Mineral Filler, U. S. Department of Agriculture Bulletin 555, p. 33.

This specification is intended to cover the mineral constituents of a roughly proportioned bituminous concrete consisting of from 45 to 60 per cent gravel or coarse aggregate, from 30 to 45 per cent sand or fine aggregate, from 3 to 5 per cent mineral filler, and from 5 to 8 per cent bitumen. This mixture should preferably be

placed upon a cement concrete foundation so as to produce, after rolling, a wearing course 2 inches in depth. A seal coat of bituminous material should then be applied and covered with pea gravel in sufficient quantity to take up all excess of bitumen.

Such roads may be maintained with surface treatments of bituminous material, covered with material conforming to Specification RS–2.

SPECIFICATION SgW 2.

Slag for Water-Bound Base.

General. The broken slag shall consist of angular fragments, reasonably uniform in density and quality, free from metallic iron, thin or elongated pieces, dirt, or other objectionable matter.

Physical Properties. The slag shall meet the following requirements:

Weight in pounds per cubic foot, each size specified, not less than	70
French coefficient of wear, not less than	5

Screenings. That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than	95
Total passing ¼-inch screen	40 to 80

Coarse Slag. That portion of the product of the crusher, which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 3-inch screen, not less than	95
Total passing 2-inch screen	25 to 75
Retained on 1-inch screen, not less than	85

Methods of Testing. The tests of the physical properties and sizes of the slag shall be made in accordance with the following methods:

1. Weight per Cubic Foot, U. S. Department of Agriculture Bulletin 555, p. 32 (6).
2. French Coefficient of Wear, U. S. Department of Agriculture Bulletin 347, p. 5.
3. Grading, U. S. Department of Agriculture Bulletin 555, p. 32 (8).

This specification provides primarily for slag to be used in the construction of a water-bound base upon which some higher type of wearing course will be placed, preferably after the base has been finally compacted by traffic. For a light traffic road it may also serve for both foundation and wearing course, provided the thickness of each is not less than 4 inches.

SPECIFICATION Sd–1.

Natural Sand Clay or Topsoil Mixtures for Road Surfacing.

General. The sand clay or topsoil shall be composed of a uniform mixture of hard durable fragments of sand, together with silt and clay, and may advantageously carry a considerable amount of gravel. The mixture should be free from an excess of feldspar or mica.

Quality. Cementing value of material under ¼ inch shall be not less than--- 35

Grading. The material which will pass a 10-mesh sieve when tested by means of laboratory sieves shall meet the following requirement for grading:

	Per cent.
Clay	10 to 25
Silt	10 to 25
Total sand	50 to 80

Methods of Testing. Tests of the cementing value and grading of the sand clay or topsoil shall be made in accordance with the following methods:

Cementing value, U. S. Department of Agriculture Bulletin 347, p. 19.

Grading, U. S. Department of Agriculture Bulletin 555, p. 33.

This specification is intended to cover the quality and approximate grading of natural sand clay and topsoil mixtures for use particularly in the South Atlantic States.

The limits of sizes are drawn so as to exclude only sand clay and topsoil of manifestly inferior grading. Where heavy traffic is to be expected, and likewise in cases where the available material warrants, the minimum allowable percentage of sand should be increased and the corresponding maximum allowable per centage of both clay and silt decreased. In cases where it is desired to construct a sand-clay road by admixing sand and clay in place, the amounts of each to be incorporated should be so gauged that the combined material, after thorough mixing, will grade approximately within the limits here shown.

The maintenance of a sand-clay road should be continuous. Patching should be done with material as nearly like that used in the original surface as possible.

SPECIFICATION Ct–1.

Portland Cement.

Definition.

(1) Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination except water and calcined or uncalcined gypsum.

I. CHEMICAL PROPERTIES.

Chemical Limits.

(2) The following limits shall not be exceeded:

	Per cent.
Loss on ignition	4.00
Insoluble residue	.85
Sulphuric anhydride (SO_3)	2.00
Magnesia (MgO)	5.00

II. PHYSICAL PROPERTIES.

Specific Gravity.

(3) The specific gravity of cement shall be not less than 3.10. Should the test of cement as received fall below this requirement, a second test may be made upon an ignited sample. The specific-gravity test will not be made unless specifically ordered.

Fineness.

(4) The residue on a standard 200 mesh sieve shall not exceed 22 per cent by weight.

Soundness.

(5) A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

Time of Setting.

(6) The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used, or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

Tensile Strength.

(7) The average tensile strength in pounds per square inch of not less than three standard mortar briquets composed of 1 part cement and 3 parts standard sand, by weight, shall be equal to or higher than the following:

Age at test.	Storage of briquets.	Tensile strength per square inch.
Days.		*Pounds.*
7	1 day in moist air, 6 days in water	200
28	1 day in moist air, 27 days in water	300

(8) The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

III. PACKAGES, MARKING, AND STORAGE.

Packages and Marking.

(9) The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net.

Storage.

(10) The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

IV. INSPECTION.

Inspection.

(11) Every facility shall be provided the purchaser for careful sampling and inspection either at the mill or at the site of the work, as may

be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test; and at least 31 days shall be allowed for the completion of the 28-day test. The 28-day test shall be waived only when specifically ordered.

V. REJECTION.

Rejection.

(12) The cement may be rejected if it fails to meet any of the requirements of these specifications.

(13) Cement shall not be rejected on account of failure to meet the fineness requirement if, upon retest after drying at 100° C. (212° F.) for one hour it meets this requirement.

(14) Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

(15) Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

Methods of Testing.

The cement shall be tested in accordance with the following methods: Tests for Portland cement, A. S. T. M. Standard, C9–17.

This is the United States Government specification for Portland cement, as described in Bureau of Standards Circular No. 33. It is also Standard Specification C9–17 of the American Society for Testing Materials. It is intended to apply wherever Portland cement is used.

SPECIFICATION Br–1.

Vitrified Paving Brick, Cushion Sand, and Grouting Sand for Brick Pavement.

VETRIFIED PAVING BRICK.

General.

All brick shall be of a size commercially known as four-inch brick. They shall be thoroughly annealed, tough and durable, regular in size and shape, and evenly burned. When broken, the brick shall show a dense, stonelike body, free from lime, air pockets, cracks, or marked laminations. Kiln marks shall not exceed $\frac{3}{16}$ of an inch, and the wearing surface shall show but slight kiln marks.

Rattler Test.

Representative samples of the brick shall meet the following requirements when subjected to the rattler test:

Average loss by abrasion on one or more samples, not more than 22 per cent.

Maximum difference in per cent loss by abrasion when more than one representative sample is tested, not more than 8 per cent, provided, however, that no sample shall show more than 24 per cent loss.

A maximum of three tests may be used as a basis for rejection.

Dimensions.

The brick shall meet the following requirements:

	Inches.
Length	$8\frac{1}{4}$ to $9\frac{1}{4}$
Width	$3\frac{1}{4}$ to $3\frac{3}{4}$
Depth	$3\frac{7}{8}$ to $4\frac{1}{8}$

Variations among brick from a single plant shall not exceed the following limits:

	Inch.
Variation in length	$\frac{1}{2}$
Variation in width	$\frac{1}{4}$
Variation in depth	$\frac{1}{8}$

If the edges of the brick are rounded, the radius shall not exceed $\frac{3}{16}$ of an inch.

Only bricks with lugs or projections on one side, raised not less than $\frac{1}{8}$ of an inch, nor more than $\frac{1}{4}$ of an inch, shall be used.

The ends of the brick shall have either a semicircular groove with a radius of not less than $\frac{1}{8}$ of an inch nor more than $\frac{1}{4}$ of an inch, or a bulge of at least $\frac{1}{16}$ of an inch.

The name or trade-mark of the manufacturer, if shown on the brick, shall be recessed and not raised.

Visual Inspection.

The brick shall be subjected to inspection subsequent to delivery at the place of use, prior to and during laying, in order to cull out and reject upon variations from the general and dimensions clauses and upon the following grounds:

All brick which are broken through, or chipped in such manner that neither wearing surface remains substantially intact, or in such manner that the lower or bearing surface is reduced in area by more than one-eighth.

All brick which are cracked to a depth greater than $\frac{1}{8}$ inch on any surface, or which are cracked on the wearing surface.

All brick which are so offsize or so misshaped, bent, twisted, or kiln marked that they will not form a proper surface or align properly with other brick.

All brick which are obviously too soft and too poorly vitrified to endure street wear.

SAND FOR CUSHION.

General.

The sand shall pass a $\frac{1}{4}$-inch laboratory screen and shall be well graded from coarse to fine. The material removed by the elutriation test, consisting chiefly of clay and loam, shall not exceed 5 per cent by weight.

SAND FOR GROUTING.

The sand shall consist of clean, hard, durable, uncoated stone particles, preferably siliceous, and free from lumps of clay and all organic matter.

It shall be well graded from coarse to fine and, when tested by means of laboratory sieves, shall meet the following requirements:

	Per cent.
Passing 10-mesh sieve	100
Passing 20-mesh sieve, not less than	80
Passing 100 mesh sieve, not more than	10

Not more than 5 per cent by weight shall be removed by the elutriation test.

When the sand is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

Methods of Testing.

Tests of the physical properties of the brick and sand shall be made in accordance with the following methods:

1. Rattler Test, A. S. T. M. Standard, C7–15.
2. Grading of Sand, U. S. Department of Agriculture Bulletin 555, p. 33.
3. Elutriation Test for Sand, U. S. Department of Agriculture Bulletin 555, p. 32.
4. Mortar Tensile Strength Test for Sand, A. S. T. M. Standard, C9–17.

SPECIFICATION Br–2.

Vitrified Paving Brick, Cushion Sand, and Grouting Sand for Brick Pavement.

VITRIFIED PAVING BRICK.

General. All brick shall be of a size commercially known as "3-inch brick." They shall be thoroughly annealed, tough and durable, regular in size and shape, and evenly burned. When broken, the bricks shall show a dense, stonelike body, free from lime, air pockets, cracks, or marked laminations. Kiln marks shall not exceed $\frac{3}{16}$ of an inch, and the wearing surface shall show but slight kiln marks.

Rattler Test. Representative samples of the brick shall meet the following requirements when subjected to the rattler test:

Average loss by abrasion on one or more samples, not more than 26 per cent.

Maximum difference in per cent loss by abrasion when more than one representative sample is tested, not more than 8 per cent, provided, however, that no sample shall show more than 28 per cent loss.

A maximum of three tests will be used as a basis for rejection.

Dimensions. The brick shall meet the following requirements:

	Inches.
Length	8 to 9
Width	$3\frac{1}{2}$ to 4
Depth	$2\frac{7}{8}$ to $3\frac{1}{8}$

Variations among brick from a single plant shall not exceed the following limits:

	Inch.
Variation in length	$\frac{1}{2}$
Variation in width	$\frac{1}{8}$
Variation in depth	$\frac{1}{8}$

Visual Inspection. Only brick with lugs on one side, raised not less than $\frac{1}{8}$ of an inch and not more than $\frac{1}{4}$ of an inch, shall be used.

The ends of the brick shall have either a semicircular groove with a radius of not less than $\frac{1}{8}$ of an inch or more than $\frac{1}{4}$ of an inch, or a bulge of at least $\frac{1}{16}$ of an inch.

The name or trade-mark of the manufacturer, if shown on the brick, shall be recessed and not raised.

The bricks shall be subjected to inspection subsequent to delivery at the place of use, prior to and during laying, in order to cull out and reject upon variations from the general and dimensions clauses and upon the following grounds:

All bricks which are broken through, or chipped in such manner that neither wearing surface remains substantially intact, or in such manner that the lower or bearing surface is reduced in area by more than one-eighth.

All bricks which are cracked to a depth greater than $\frac{1}{8}$ inch on any surface, or which are cracked on the wearing surface.

All bricks which are so offsize or so misshaped, bent, twisted, or kiln marked that they will not form a proper surface or align properly with other bricks.

All bricks which are obviously too soft and too poorly vitrified to endure street wear.

SAND FOR CUSHION.

General. The sand shall pass a $\frac{1}{4}$-inch laboratory screen and shall be well graded from coarse to fine. The material removed by the elutriation test, consisting chiefly of clay and loam, shall not exceed 5 per cent by weight.

SAND FOR GROUTING.

General.

The sand shall consist of clean, hard, durable, uncoated-stone particles, preferably siliceous, free from lumps of clay and all organic matter.

It shall be well graded from coarse to fine and, when tested by means of laboratory screens and sieves, shall meet the following requirements:

	Per cent.
Passing a 10-mesh sieve	100
Passing a 20-mesh sieve, not less than	80
Passing a 100-mesh sieve, not more than	10

Not more than 5 per cent by weight shall be removed by the elutriation test.

When the sand is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand by weight, according to standard methods of making 1 : 3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

Methods of Testing.

Tests of the physical properties of the brick and sand shall be made in accordance with the following methods:

1. Rattler Test, A. S. T. M. Standard, C7–15.
2. Grading of Sand, U. S. Department of Agriculture Bulletin 555, p. 33.
3. Elutriation Test for Sand, U. S. Depuartment of Agriculture Bulletin 555, p. 32.
4. Mortar Tensile Strength Test for Sand, A. S. T. M. Standard C9–17.

These specifications cover vitrified paving brick, cushion sand, and grouting sand for brick wearing course, and sand cushion for two sizes of brick.

The sand cushion or sand cement cushion should preferably be placed upon a concrete foundation to a depth after rolling of not over 1½ inches. This cushion should be shaped to the desired cross section of the finished wearing course before placing the brick. After laying and rolling the brick, the joints are filled with a grout composed of equal parts of cement and grouting sand reduced with water to a creamy consistency. If desired, a bituminous mastic or a bituminous filler may be poured hot into the joints. In the latter case, the requirement for grouting sand and all reference thereto should be eliminated from the specifications.

SPECIFICATION R–1.

Granite Block, Gravel, and Sand for Stone-Block Pavement.

STONE BLOCK.

General. The stone block shall be of granite of medium-sized grain, showing an even distribution of constituent minerals. They shall be of uniform quality and texture throughout, and free from seams, scales, or disintegrated material.

Physical Properties. Sample blocks shall meet the following requirement:

French coefficient of wear, not less than	8
Toughness, not less than	7

Dimensions. The blocks shall meet the following requirements:

	Inches.
Length on top	8 to 12
Width on top	3½ to 4½
Depth	4¾ to 5¼

Visual Inspection. The stone block shall be subjected to inspection subsequent to delivery at the place of use, prior to and during laying, in order to cull out and reject those which fail to conform with the general and dimension clauses and the following requirements of this specification:

The blocks shall be so dressed that when laid as specified measurement of any joint shall show a width of not more than ½ inch for a depth of 1 inch, or a width of not more than 1 inch in any part of the joint.

The wearing surface of the blocks shall show no depressions more than ⅜ inch deep, and the edges and corners shall be unchipped and unbroken.

SAND FOR CUSHION.

Grading. The sand shall pass a ¼-inch laboratory screen, and shall be well graded from coarse to fine. The material removed by the elutriation test, consisting chiefly of clay and loam, shall not exceed 5 per cent by weight.

SAND FOR GROUTING.

General. The sand shall consist of clean, hard, durable, uncoated stone particles, preferably siliceous, free from lumps of clay and all organic matter.

Grading. It shall be well graded from coarse to fine and, when tested by means of laboratory screens, shall meet the following requirements:

	Per cent.
Passing 10-mesh sieve	100
Passing 20-mesh sieve, not less than	80
Passing 100-mesh sieve, not more than	10

Not more than 5 per cent by weight shall be removed by the elutriation test.

Mortar Strength Test. When the sand is mixed with Portland cement in the proportions of 1 part of cement to 3 parts of sand by weight, according to standard methods of making 1 : 3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

GRAVEL FOR FILLER.

General. The gravel shall be composed of clean, hard, durable fragments of rock.

Grading. When tested by means of laboratory screens it shall meet the following requirements:

	Per cent.
Passing ½-inch screen, not less than	95
Retained on ¼-inch, not less than	85

Methods of Testing. Tests of the physical properties of the block, gravel, and sand shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 4.
2. Toughness, U. S. Department of Agriculture Bulletin 347, p. 15.

3. Grading of gravel and sand, U. S. Department of Agriculture Bulletin 555, p. 33.
4. Strength test of sand, U. S. Department of Agriculture Bulletin 555, p. 32.
5. Elutriation test of sand, A. S. T. M. Standard, C9–17.

This specification covers granite block, cushion sand, grouting sand, and gravel filler to be used in the construction of a stone-block wearing course and sand cushion.

The requirements for quality of block here given are on the basis of a pavement subjected to comparatively moderate traffic. For very heavy traffic, a French coefficient of wear of 10.0 or 11.0 and a toughness of 9 or 10 may reasonably be required. While a coefficient of hardness of not less than 16 might well be included under physical properties, a requirement for French coefficient of wear has been used instead, owing to the fact that but few laboratories are equipped with a Dorry hardness machine.

The sand cushion, or sand cement cushion, should be placed upon a concrete foundation to a depth of from 1 to 1½ inches and should be carefully shaped to the cross section of the finished pavement at such a height that the blocks after consolidation are at grade. The blocks are usually laid in straight rows at right angles to the curb, with joints broken at least 3 inches, and are rammed to a solid bearing before filling. Joints in block pavements may be filled with either a cement grout, bituminous mastic, or gravel with a poured bituminous filler. Grouting sand as called for in this specification may be used with either Portland cement to form the sand-cement grout, or a bituminous material to form a bituminous mastic. If a gravel and bituminous filler is to be used the requirements for grouting sand and all reference thereto should be eliminated from the specifications.

APPENDIX I.

METHODS OF TESTING.

The following methods of testing are those to which reference is made in the foregoing specifications. In some cases the descriptions from the original references have been condensed, but not changed in any essential particular.

French Coefficient of Wear of Rock or Slag. (Bulletin 347, page 5.)—The determination of the French coefficient of wear is made in an apparatus known as the Deval abrasion machine, shown in figure 1. This machine consists essentially of a number of cast-iron cylinders 20 cm. in diameter and 34 cm. deep inside, which are mounted upon a frame in such a manner that the axes of the cylinders are inclined at an angle of 30 degrees with the axis of revolution of the frame. The following method is essentially the American Society for Testing Materials Standard Test D2–08.

The material to be tested is broken into pieces as nearly of the same size and shape as practicable, so that approximately 50 pieces shall weight, after thorough drying, to within 1 gram of 5,000 grams. In no case should the number of pieces exceed 60 or be less than 40. Care should be taken to use only freshly broken fragments, as pieces with rounded edges greatly affect the results. The pieces may be so broken as to average from 2 to $2\frac{1}{2}$ inches in diameter with the assurance of ordinarily obtaining a properly sized sample. After weighing, the sample is placed in one of the cylinders of the Deval machine, the cover bolted on, and the machine given 10,000 revolutions at the rate of 30 per minute. At the conclusion of the test the sample is screened over a laboratory screen having $\frac{1}{16}$-inch square openings, the material retained thoroughly washed free from dust, dried in an oven, and again weighed. The difference between this weight and that first obtained represents the wear as determined by test.

The following formula, in which "a" represents the final weight of the washed and dried stone, may be used to calculate the French coefficient of wear:

$$\text{French coefficient of wear} = \frac{2000}{5000 - a}$$

Toughness of Rock. (Bulletin 347, page 15.)—The following test for toughness is essentially the same as the American Society for Testing Materials tentative Standard Test D3–17T. It is made on a cylinder 25 mm. long and from 24 to 25 mm. in diameter, cut from the sample of rock to be tested by means of a diamond drill. In cases where any evidences of lamination or foliation exists, two sets of cores are prepared, one set at right angles to and the other set parallel to the foliations. Specimens a little over 25 millimeters long are next cut from the rock cores by means of a diamond saw. The ends are then ground plane on a grinding lap until they are exactly 25 millimeters long. Although it is not necessary that the two ends of the specimens be exactly parallel, one surface of each at least should be as nearly perpendicular

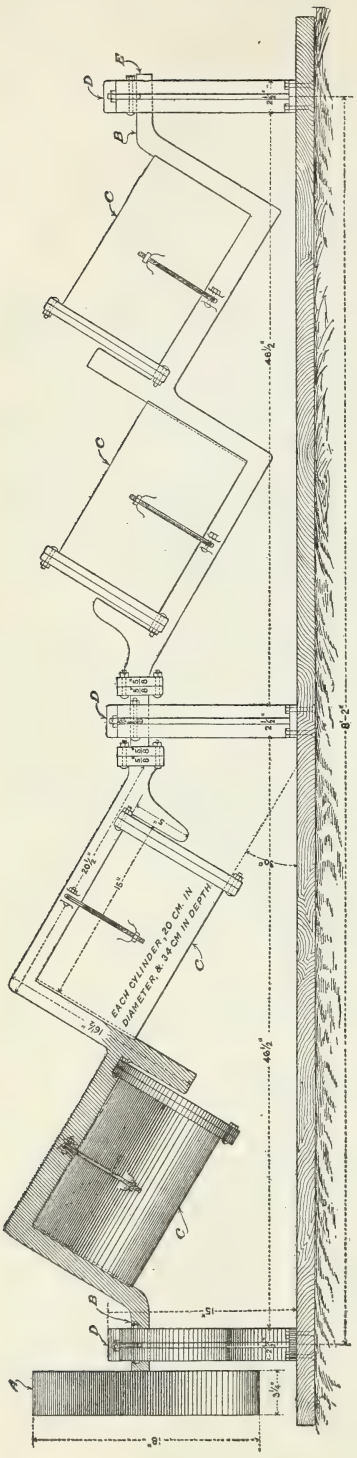

FIG. 1.—Abrasion machine—Deval type (front view).

to the axis of the cylinder as it is possible to make it. After drying and cooling, a specimen to be tested is placed on the anvil (W) of a Page impact machine, shown in figure 2, taking extreme care that when in position the specimen rests with a perfect bearing on the anvil and that the spherical end of the plunger is tangent to the specimen exactly in the center of its upper surface. The small thumbscrew used for separating the clips which hold the specimen in place should be so adjusted that the clips hold the test piece firmly without any undue pressure on the spring. Attention to these details is very important if accurate results are to be obtained. When the specimen is in position the current is turned on the magnet and the upper cross-head is lowered until the rod projecting from it just comes in contact with the rod projecting from the lower cross-head (M). This occurs at the instant the pilot lamp, in series with the magnet circuit, flashes out. The dial (Q) is then adjusted to O, the upper cross-head raised 1 centimeter, and the motor started. After each blow the fall of the hammer is increased 1 centimeter until failure of the test piece occurs.

The height in centimeters of the blow at failure is recorded as the toughness of the material, using for the final value the average of three determinations. In the case of foliated rock the average of three determinations in each direction is taken as the toughness of the sample.

Weight per Cubic Foot of Broken Slag.—The weight per cubic foot should be determined by shaking the dried slag to refusal in a cubic foot cylindrical measure. About $\frac{1}{3}$ of the total amount of slag necessary to fill the measure is first introduced in such a manner as to avoid any separation of sizes. This material is then shaken down by rocking the measure from side to side until no further settlement takes place. This process is repeated until the measure has been filled to overflowing, after which it is struck off level with the top with a straight edge and weighed.

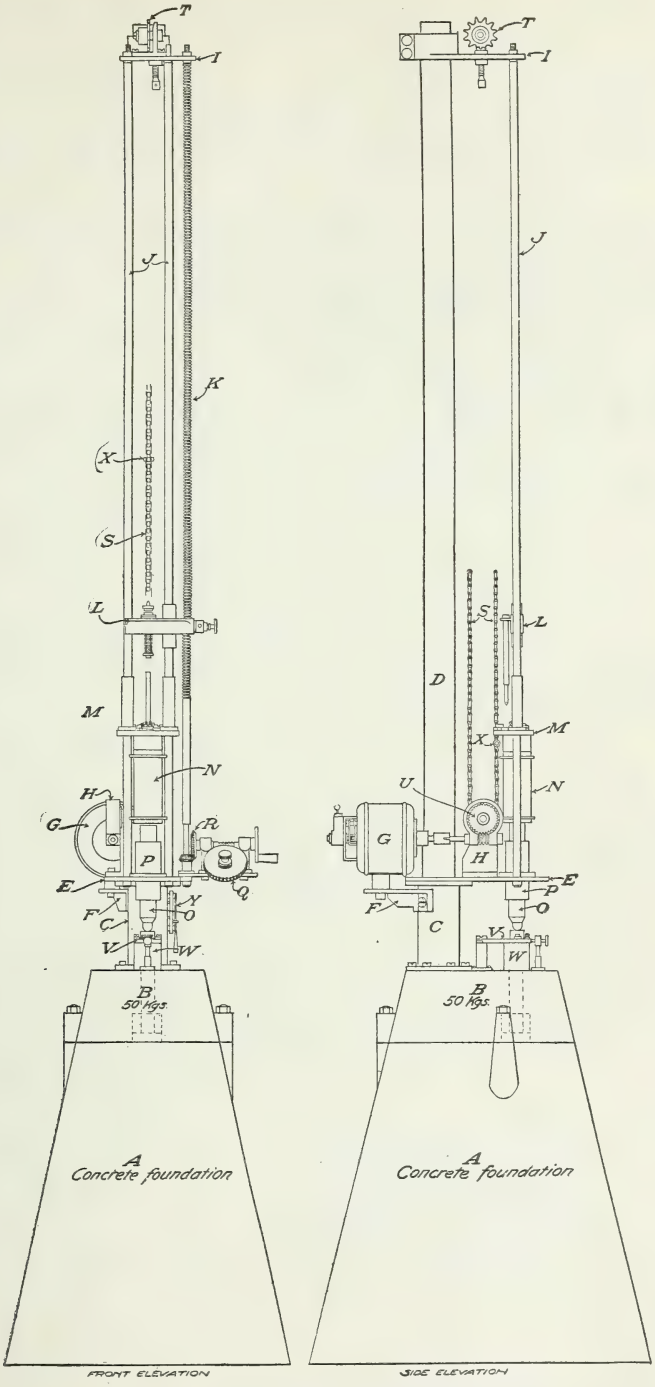

FIG. 2.—Details of Page impact testing machine.

Size, Grading, or Mechanical Analysis of Broken Stone, Broken Slag, or Gravel. (Bulletin 555, page 32 (8).)—A sample of the material weighing not less than fifty (50) times the weight of the largest size stone present is used. After drying at not over 110° C. (230° F.) to constant weight, the sample is passed through such of the following size screens, having circular openings, as are required or called for by the specifications, screens to be used in the order named: 3½-inch, 3-inch, 2½-inch, 2-inch, 1½-inch, 1-inch, ¾-inch, ½-inch, and ¼-inch.

The percentage by weight, retained on each screen, is determined and the mechanical analysis is recorded in the following manner:

	Per cent.
Passing 3½-inch screen and retained on 3-inch screen	
Passing 3-inch screen and retained on 2½-inch screen	
Passing 2½-inch screen and retained on 2-inch screen	
Passing ½-inch screen and retained on ¼-inch screen	
Passing ¼-inch screen	

Elutriation Test of Sand. (Bulletin 555, page 32.)—The entire sample is moistened and thoroughly mixed, and a sample weighing approximately 105[1] grams is obtained for elutriation and grading by quartering or by selecting small portions from various parts of a flat pile. The sample is then dried at not over 110° C. (230° F.). This dried sample is accurately weighed and placed in a 500-cc.[1] beaker, and about 350 cc.[1] of water is added and agitated in such manner that no whirling results. After settling for 20 seconds, the water is poured off through a 200-mesh sieve, and the operation of agitation, sedimentation, and decantation repeated until the wash water is approximately clear. Particles caught on the 200-mesh sieve are then washed back into the washed sample remaining in the beaker. The entire washed sample is dried to constant weight and accurately weighed, and the

$$\text{Per cent by elutriation} = \frac{\text{Original weight} - \text{Final weight}}{\text{Original weight}} \times 100.$$

Mechanical Analysis or Grading of Sand or Fine Aggregate. (Bulletin 555, page 33.)—All of the dried sample remaining after the elutrition test, if such is required, is passed successively through the desired screens and sieves, beginning with either the largest or smallest as may be convenient. Where an elutriation test is not required, a dried sample of the original material weighing about 100 grams is used.

The percentage, by weight, of the unwashed sample retained on each screen is determined, and the mechanical analysis is recorded according to one or both of the following methods. A screen with ¼-inch circular openings is used, together with square-mesh sieves as specified in A. S. T. M. Standard Methods D7–16.

	Per cent.
Total retained on ¼-inch screen	
Passing ¼-inch screen and retained on 10-mesh sieve	
Passing 10-mesh sieve and retained on 20-mesh sieve	
Passing 20-mesh sieve and retained on 30-mesh sieve	
Passing 30-mesh sieve and retained on 40-mesh sieve	
Passing 40-mesh sieve and retained on 50-mesh sieve	
Passing 50-mesh sieve and retained on 80-mesh sieve	
Passing 80-mesh sieve and retained on 100-mesh sieve	
Passing 100-mesh sieve and retained on 200-mesh sieve	
Passing 200-mesh sieve	
Total	100

[1] If the sand is so coarse that a 100-gram sample is not sufficient, the size of the sample, the container, and the amount of water used may be proportionately increased.

	Per cent.
Total passing ½-inch screen	
Total passing 10-mesh sieve	
Total passing 20-mesh sieve	
Total passing 30-mesh sieve	
Total passing 40-mesh sieve	
Total passing 50-mesh sieve	
Total passing 80-mesh sieve	
Total passing 100-mesh sieve	
Total passing 200-mesh sieve	
Passing 200-mesh sieve elutriation	

Washing Test and Grading or Mechanical Analysis of Road Gravel. (Bulletin 555, page 32 (9).—A sample of the material weighing not less than 50 times the weight of the largest size stone present is used. After thoroughly drying at 100° C. (212° F.) in a hot-air bath, the sample is cooled, weighed, and placed in a shallow pan, covered with water, and thoroughly agitated by means of a trowel for 15 seconds. After 15 seconds sedimentation the water is poured off through a 200-mesh sieve, and the operation of agitation, sedimentation, and decantation repeated until the wash water is approximately clear after 15 seconds. The washed material, together with any residue retained on the 200-mesh sieve, is then dried to constant weight, cooled and weighed and passed through such of the following size screens and sieves as are called for in the specification, using them in the order named:

Screens (circular openings): 3-inch, 2½-inch, 2-inch, 1½-inch, 1-inch, ¾-inch, ½-inch, and ¼-inch.

Sieves, A. S. T. M. Standard Method (square mesh): 10, 20, 30, 40, 50, 60, 80, 100, and 200 meshes per linear inch.

The percentage by weight retained on each screen or sieve and based on the weight of the original sample is calculated, using for the determination of the percentage of material passing the 200-mesh sieve the sum of the weights of material passing this sieve by analysis and by washing.

Cementing Value of Gravel, Top Soil, or Sand Clay. (Bulletin 347, page 15).—A 500-gram sample of that portion of the material which will pass a ¼-inch screen is placed in a ball mill with 18 per cent water, and the machine given 5,000 revolutions at the rate of 30 per minute. After grinding the resulting dough is removed and molded in a hydraulic briquetting machine into briquettes 25 mm. in diameter and 25 mm. high, under a pressure of 132 kg. per sq. cm. Six briquettes should be made from each sample. They are allowed to dry in the air at ordinary room temperature for 20 hours after making, and are then dried at a temperature of 100° C. for four hours, cooled for 20 minutes in a desiccator, and immediately tested. In making the test the briquette is held in position on the anvil of a Page cementing-value-impact testing machine (fig. 3) by means of a drop of thick shellac, extreme care being taken to see that there is perfect contact between the upper surface of the briquette and the plunger, as well as between its lower surface and the anvil. With the briquette in position, the plunger resting on it, and the cam in the position shown in figure 3, the end of the pin (F) is brought into contact with the surface of the cam and the locknut tightened. This will give an effective drop of 1 cm. to the hammer. The brass pencil is so adjusted that on revolving the drum a horizontal line will be traced on a piece of sensitized paper which has been wrapped around it. On starting the motor, each blow of the hammer will then be recorded in a short vertical line above the base line. The number of blows required to destroy the resilience of the briquette will equal the number of vertical lines showing on the record above the base line. In counting the number of vertical lines showing on the record, no attention should be paid

to the fact that the short horizontal lines gradually drop below the original base line. Each vertical line which shows above the corresponding horizontal base line on its right should be counted as part of the record.

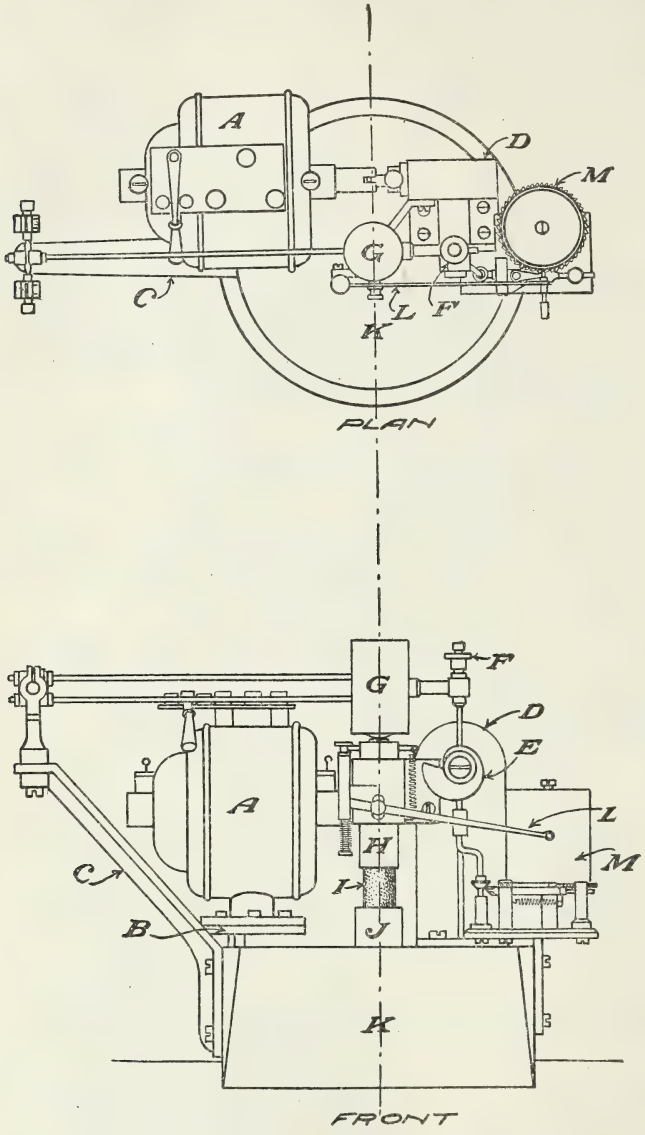

FIG. 3.—Details of Page impact machine for testing cementing value.

The number of blows required to destroy the specimen is called its cementing value. An average of five determinations is taken.

Washing Test and Grading, or Mechanical Analysis of Sand-Clay or Top-Soil. (Bulletin 555, page 35.)—A 500-gram sample of the material is dried at a temperature below 350° F. (176.6° C.) to constant weight, and is gently pulverized to break down soft clods or masses, but not so as to grind or break hard material. The sample is then passed through a 10-mesh sieve, the coarse residue weighed and recorded as "coarse material." The material passing the 10-mesh sieve is then used as the starting point of a percentage analysis as follows:

Two samples of 50 grams each of this material are weighed out for duplicate analysis. Each is placed in a wide-mouth bottle (5 to 6 cm. diameter and about 12 to 15 cm. high), and about 5 c. c. of dilute ammonia water and about 200 c. c. of water is added. After thoroughly shaking for about 20 minutes, the sample is allowed to settle 8 minutes and the supernatant liquid decanted. The process is repeated until the supernatant liquid is clear. The washings drawn off may be collected and evaporated to dryness for direct recovery of the fine sediment classed as "*clay*." Ordinarily the sediment loss is computed as difference.

The content of the bottle is washed into a porcelain evaporating dish and carried to dryness on a water bath. The dried residue is then passed through a nest consisting of a 20, 60, 100, and 200 mesh sieve. The residue retained on each sieve is weighed and recorded as *sand* of the respective size. Their sum constitutes the "*total sand*." The residue passing the 200-mesh sieve and caught in the pan is weighed and recorded as "*silt*." Duplicate samples should check within 1 per cent.

Tests for Portland Cement. (A. S. T. M. Standard Test C9–17.)—The generally adopted standard methods of testing Portland cement have been so widely circulated through Bureau of Standards Circular No. 33, and publications of the American Society for Testing Materials, that it is thought unnecessary to include them in this bulletin. These tests cover chemical analysis, specific gravity, fineness, soundness, time of setting, and tensile strength.

Mortar Tensile Strength Test for Sand. (Based on A. S. T. M. Standard Test C9–17.)—This test is preferably made with the same brand of cement that will be used in construction, but any Portland cement which meets the standard specifications will serve. Briquets composed of three parts of the sand, which has first been passed through a ¼-inch laboratory screen, to one of cement are made of as near as possible the same consistency as ordinary standard mortar briquets, a set of which should be made at the same time. Such consistency can only be obtained by trial. In general, slightly more water will be required for an ordinary concrete sand than for the standard Ottawa sand. The mortar should be of such consistency after thorough mixing that after squeezing in the hand it will stick together and still retain its shape. If the consistency is other than this, a fresh batch of mortar should be made with more or less water as indicated and the trial repeated until the proper consistency is secured. This is preferable to adding water to a batch of mortar which may have been found to be too dry.

Immediately after mixing, the mortar is placed in the standard molds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar should be heaped above the mold and smoothed off with a trowel, which should be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold should then be turned over and the operation of heaping, thumbing, and smoothing off repeated. The briquets must be kept in molds on glass plates in a moist closet for

at least 20 hours. After 24 hours in moist air, the briquets are immersed in clean water in storage tanks of non-corroding material. The air and water should be maintained as nearly as practicable at a temperature of 21° C. (70° F.). The moist closet may consist of a soapstone, slat, or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with nonabsorbant shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily. Tests may be made with any standard machine. The briquets are tested as soon as they are removed from the water. The bearing surfaces of the clips and briquets must be carefully centered and the load applied continuously at the rate of 600 pounds per minute. Testing machines should be frequently calibrated in order to determine their accuracy. Briquets that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all test pieces made from the same sample and broken at the same period, should not be considered in determining the tensile strength. The average tensile strength in pounds per square inch of not less than three briquets is compared with the average tensile strength of not less than three standard mortar briquets made at the same time and by the same operator wtih the same cement and Ottawa sand.

Rattler Test for Paving Brick. (A. S. T. M. Standard Test C7–15.)—Foliowing is a brief description of the rattler test. For a detailed description reference should be made to the book of A. S. T. M. Standards, 1916.

The standard rattler test is used for the purpose of determining the resistance to wear of vitrified paving brick. The machine should conform in every respect to the standard requirements covering the construction of the rattler. The abrasive charge consists of 10 cast-iron spheres, weighing when new $7\frac{1}{2}$ pounds each, and a sufficient number of small spheres, weighing when new 0.95 pounds each, to bring the collective total weight of the charge to as nearly 300 pounds as possible. Both small and large spheres should be standardized from time to time, as called for in the detail specification. The brick charge consists of 10 brick, none of which would be rejected on visual inspection. They should be thoroughly dried previous to testing. The test consists of subjecting the brick to 1800 revolutions of the rattler at the rate of not less than $29\frac{1}{2}$ nor more than $30\frac{1}{2}$ revolutions per minute. At the conclusion of the test, the brick are reweighed, rejecting any piece weighing less than 1 pound. The percentage of wear is calculated from the following formula:

$$\text{Per cent wear} = \frac{\text{Original weight—final weight}}{\text{Original weight}} \times 100.$$

APPENDIX II.

METHODS OF SELECTING AND SHIPPING SAMPLES.

The following directions for selecting and shipping samples of nonbituminous materials should be followed in connection with materials which are to be tested in the laboratory for conformity with the foregoing specifications. It should be noted that most of the tests for size or grading of broken stone, slag, gravel, sand, etc., may and should be made frequently in the field or at the plant with a set of screens or sieves and a rough balance.

General Directions.—(1) Samples should be taken so as to represent as nearly as possible an average of the bulk of material sampled, and in case of principal materials for the higher types of roads, they should also be selected with a view to ascertaining the maximum variation in characteristics which the materal may possess. (2) Samples should be packed in such manner as to withstand rough shipment, and special precautions should be taken to prevent the obliteration or removal in transit of tags or identification marks. (3) Notification of shipment of samples, with statement of identification marks and such other descriptive information as may be necessary should be promptly forwarded to the laboratory.

Information Accompanying Samples.—Whenever possible, the following information should be furnished the laboratory in connection with each sample submitted:

1. Identification mark.
2. Name of material.
3. Name and address of producer, or owner of deposit.
4. Location of plant or deposit.
5. To be examined for conformity with ——— specification.
6. Name and location of road where material is to be used.
7. Proposed use and type of construction in which material is to be used.
8. Date sample taken.
9. Place sample taken.
10. Sample taken from (quarry, crusher, bin, pit, plant, car, storage pile, or mixer).
11. Quantity represented by sample.
12. Material shipped in car No. ——.
13. Date material shipped.
14. Date material received at destination.
15. Date used or to be used if satisfactory.

Time and Plant of Sampling.—(1) Whenever practicable, nonbituminous materials should be sampled at the place of occurrence or manufacture at such time as to allow the test controlling acceptance or rejection to be made in advance of shipment. (2) When impracticable to take samples as above mentioned, they should be taken from the shipment immediately upon delivery. (3) Samples should always be taken when the appearance or quality of the material changes.

BROKEN STONE.

Sampling for Quality.—When tests for physical properties are required, a preliminary sample should be taken from each proposed source of supply at least two weeks before final acceptance. The preliminary sample may, however,

be omitted in cases where material from a well-known source of supply has been tested within one year previous to the date of acceptance or rejection. In such case the report of the last previous test may be used as the basis of acceptance or rejection. Mixed samples may be taken when deemed necessary. Each sample should weigh at least 25 pounds and be composed only of sound interior rock strictly representative of that which it proposed to use. The fragments should be 2 inches in size or larger. In addition, one piece which should measure at least 3 by 4 by 6 inches will be required if a toughness test is to be made. This piece should be free from seams and cracks, and should have the bedding plane marked if practicable. Samples should be shipped in tight boxes or heavy burlap bags.

Sampling for Size or Grading.—Broken stone may be sampled for size at the crusher, from bins, cars, or storage piles on the job. A composite sample composed of samples from different parts of the supply is advisable. Samples should weigh not less than 10 pounds for material containing fragments ¾ inch in diameter. Samples of larger aggregates should increase in size up to about 60 pounds, depending upon the diameter and weight of the largest fragments present. When laboratory tests for size are required, samples should be shipped in tight boxes or heavy close canvas bags.

BROKEN SLAG.

Sampling for Quality.—Slag should be sampled from the crusher or that portion of the dump which it is proposed to use, at least two weeks and not more than one month before final acceptance. Additional samples should be taken during progress of the work, whenever the quality or appearance of the slag changes, and at such other times as may be directed. For the French coefficient of wear determination, each sample should weigh at least 25 pounds and be composed of fragments 2 inches in size or larger. Samples of approximately 100 pounds of each size will be needed for determinations of weight per cubic foot, but such test should ordinarily be made at the crusher or on the job. Tight boxes or heavy burlap bags should be used as containers when shipping samples of slag.

Sampling for Size or Grading.—The same directions given under broken stone apply to broken slag.

GRAVEL.

Samples of pit run gravel proposed for use in water-bound gravel road construction should be taken at least 10 days and not more than 6 months prior to the date of acceptance or rejection, and, if from an accepted source of supply, whenever, during the progress of the work, the gravel appears to change markedly in either quality or grading. Great care should always be exercised in sampling a gravel pit to insure obtaining material for test which is strictly representative of that which it is proposed to use. A number of samples may be taken from a single pit if necessary to cover the probable range in grading of the available material. Samples of pit run gravel should weigh from 50 to 75 pounds.

Samples of screened gravel may be taken at the plant, from bins, storage piles, barges, or cars. A composite sample composed of samples from different parts of the supply is advisable in order to determine the average composition of the material. Every shipment of gravel for bituminous concrete or Portland cement concrete should be sampled, in which case no single sample should represent over 100 cubic yards. Samples should weigh from not less

than 10 pounds, for material containing fragments up to ¾-inch in diameter, up to 60 pounds, depending on the size of the largest fragments present.

Shipment of samples should be made in tight boxes or close-woven cloth bags.

SAND.

Before approving a source of supply, samples of sand should be taken at least 10 days prior to the date of acceptance or rejection. Pit samples should be taken only from freshly exposed surfaces, and the number of samples from any given deposit should be sufficient to cover the extreme range in quality of that portion of the deposit which it is proposed to use. Every shipment of sand for bituminous concrete, Portland cement concrete, or grouting should be sampled, and no single composite sample should represent over 100 cubic yards. Additional samples should be taken whenever the appearance of the sand changes. In the case of sand for sheet asphalt, frequent samples should be taken daily at the plant from the drum or bin.

Samples of sand should weigh approximately 10 pounds. They should be shipped in tight boxes, case, or close-woven cloth bags.

MINERAL FILLER.

Each shipment of mineral filler should be sampled. When shipped in bags a composite sample should be prepared from one sample taken from each 20 bags in the shipment. A 1-pound sample may be submitted for examination shipped in a tight box or can.

TOTAL MINERAL AGGREGATES.

When the grading of the total mineral aggregate for bituminous concrete or binder course is specified frequent samples should be taken daily at the plant from the drum or bin. Such samples should weigh approximately 10 pounds and if shipped should be placed in tight boxes or cans.

SAND-CLAY OR TOP SOIL.

Before approving a source of supply samples of natural sand-clay mixtures, top soil, sand, or clay should be taken at least 10 days prior to the date of acceptance or rejection. The number of samples from any given deposit should be sufficient to cover the extreme range in quality of that portion of the deposit which it is proposed to use. Additional samples should be taken whenever the appearance of the material changes. When an artificial mixture is made on the road fragment samples of the finished mix should be taken. Samples should weigh approximately 10 pounds and if shipped should be placed in tight boxes or cans.

PORTLAND CEMENT.

Either individual or composite samples of cement may be submitted. Samples should be taken either at the mill or from cars. Individual samples from cars should represent not more than 50 barrels. If taken from bins, each sample should represent not more than 100 barrels. Composite samples taken from cars should be made up of a sample from 1 sack in each 40 sacks, or 10 barrels combined to form one sample. Composite samples taken at the mill may be either from the conveyor delivering to the bin, in which case one sample of 8 pounds should be taken from each 100 barrels passing over;

from the bins themselves by means of proper sampling tubes, provided samples are taken from points well distributed over the face of the bins; or from the bins at the point of discharge, provided sufficient material is drawn from each discharge to obtain samples representative of the material in the bins. In no case should a single composite sample represent over 200 barrels. Samples should be shipped and stored in air-tight containers. Before testing, they should be passed through a 20-mesh sieve in order to thoroughly mix the sample, break up lumps, and remove foreign material.

PAVING BRICK.

Samples of vitrified paving brick may be taken at the point of manufacture or from cars at the point of delivery. Samples from the plant should preferably be taken from the kiln at the time of emptying. One or more sets of tests, depending upon the size of the kiln, each set consisting of three separate tests, should be made on each kiln. Each test in a set of three should represent approximately a single degree of burning (based on the position of the brick in the kiln), and all 10 of the brick in a single test should be of the same approximate degree of burning. In general, samples selected from piles at the plant should be as nearly as possible representative of the entire run of the brick. Samples from piles should be taken from as many different points corresponding to the length, breadth, and depth of the pile as possible. In no case should they be confined to the upper or outer few layers. Where controversy arises regarding the admissibility of certain types or portions of the lot, entire test samples may be selected from such types or portions having a characteristic appearance in common. When sampled at the point of delivery, a representative sample should be taken from each carload received. Considerations covered under sampling from piles at the plant apply equally to sampling from cars. No bricks should be included in the test lot which would be rejected on the basis of cracks, chips, or other defects covered by the specification clauses for visual inspection. Samples should be shipped in stout boxes or crates in lots of 12, put up in 2 rows of 6 bricks each, separated by a wood partition.

STONE BLOCK.

Stone block may be sampled for quality and size either at the quarry or from cars. A preliminary sample for quality consisting of at least four standard blocks should be submitted from each proposed source of supply at least two weeks prior to the date of acceptance or rejection. Additional samples of blocks may be taken from time to time during the progress of the work, whenever the quality or appearance of the blocks varies, and at such other times as may be directed. No sample should include blocks which would be rejected on visual inspection. Preliminary samples may be omitted in cases where material from the proposed source of supply has been tested within one year prior to the date of acceptance or rejection, in which cases the report of such tests may be used as the basis for acceptance or rejection. Samples of stone blocks should be shipped in stout boxes or crates.

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